

RELAY INTERCROPPING WHEAT AND SOYBEANS

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INTRODUCTION

Double cropping wheat and soybeans is becoming more popular as one way to increase the per acre output of grain crops. In previous publications, the chances for success of this system were shown to be of some risk in Ohio due to insufficient moisture, weed competition, and a short growing season. Management innovations such as early wheat harvest at high moisture content, no-tillage planting of soybeans, herbicide weed control, and variety selection can help decrease the risks of this system (4, 5). Planting soybeans before wheat harvest would significantly increase the soybean yield potential as a result of a longer growing season for the soybeans.

A system where two or more crops are grown simultaneously on the same field during part of the life cycle of each is known as relay intercropping (2). Triplett, *et al.* (6) showed that 60% of the Ohio fields surveyed in 1975, where soybeans were acrially seeded into standing wheat, produced less than break-even soybean yields. Failures were due mostly to the inability to get a good stand of soybeans. Low rainfall after seeding and weeds also contributed to the poor yields.

As a result of inherent difficulties in soybean establishment with aerial seeding, investigation of planting with a no-till planter into growing wheat was started in 1975. The productivity of this method was compared with double cropping, broadcast seeding, wheat alone, and soybeans alone, each with various herbicides for weed control.

1975 EXPERIMENT

Materials and Methods

This study was conducted at Wooster in 1974-75 on a Canfield silt loam having a soil test of pH = 5.9, P = 35 lb/A, and K = 140 lb/A. Arthur-71 wheat was sown in the fall of 1974 with 15-25-50 lb/A of N, P₂O₅, and K₂O, respectively, and an additional 0-48-80 plus 2 T/A lime in March 1975. Double cropped or relay intercropped soybeans (Capitan treated) following or in the wheat were planted with a two-row no-tillage planter or surface broadcast at varying times. Wheat and soybeans alone with conventional tillage were the controls. In addition, seven herbicide treatments were tested with the cropping treatments.

Cropping plots were 10 ft wide and 175 ft long and were split into seven 25 ft long herbicide treatment subplots. Double cropped soy-

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beans were planted in eight rows 15 inches apart on June 30 where the wheat was cut and windrowed for drying, or on July 8 following wheat which was combined July 7 at about 20% moisture. Relay intercropped soybeans were planted April 21, April 30, and May 9 with a no-tillage planter in four rows, 21 inches apart, or broadcast with a drill having its furrow openers made inoperable. Seeding rate was 8-10 seeds per linear foot when planted, or about 3 bu/A when broadcast.

The soybeans were Northrup King brand Multivar-40, a blend of Group I maturity (7) varieties normally maturing in about 112 days when planted in mid-May. Planting depth was controlled close to 1½ inches by the use of depth bands. To simulate a skip-row pattern in some plots of wheat, every third row of wheat was killed with Paraquat and soybeans were planted in these skipped spaces.

Wheat was combined so that soybeans were not damaged by the combine wheels.

Results and Discussion

The results for 1975 are summarized in Tables 1 and 2. Wheat yield actually harvested was decreased by the windrowing treatment because of excessive shatter losses, which in turn resulted in excessive volunteer wheat competing with the soybeans. Relay intercropping also decreased wheat yields except where soybeans were broadcast in April. Planting soybeans caused traffic damage and decreased yield of wheat, which was more severe with progressively later plantings. Yield of wheat was depressed by the skip-row pattern but soybean yield was increased. Some of the depression of yield may have been caused by Paraquat injury from drift to untreated rows rather than the skip-row pattern alone. As expected, wheat yields from the double cropped plots were the same (within experimental error) as from wheat alone. Harvesting wheat at 20-25% moisture does not hurt quality and yield is not usually affected (8).

Double cropped soybean yields were limited by dry weather. With adequate rainfall, the long-term average yield of double cropped soybeans is about 25 bu/A. June and July rainfall was 4.2 inches below normal, resulting in slow emergence and poor early growth of the double cropped soybeans.

Windrowing wheat to allow earlier soybean planting usually results in higher double cropped soybean yields, but the difference compared to the July 8 planting was small (28 vs. 24%) as a result of drought. Later plantings of the relay intercropped soybeans gave higher yields, which were clearly related to stand. Soil temperature in April is usually too low for soybean growth, and planting early often results in poor emer-

gence. Relay intercropped soybean yields were also limited by the drought, which caused slow growth after wheat harvest.

Broadcasting soybeans was inferior to no-tillage planting in skip rows, but about equal to planting in solid-drilled wheat. Where Surflan was used (Table 2), broadcasting soybeans was inferior to other planting methods because of poor stands due to herbicide injury. For that reason, broadcasting treatments were not used in 1976.

Weed control is important if soybeans are to have some chance for success in a relay intercropping system. The herbicides were not very effective because they did not control the red clover and volunteer wheat, which were serious problems. Hoelon and Basagran are normally used post-emergence for soybeans, and are effective on some annual grasses and annual broadleaf weeds. Surflan is used pre-emergence and was somewhat more effective for controlling weeds, but the rate used caused some damage to wheat. It is not currently approved for use with wheat,

TABLE 1.—Effects of Several Cropping Systems on Yields of Wheat (Arthur-71) and Soybeans (Multivar-40), Wooster, Ohio, 1975.

Cropping System	Relative Wheat Yield Percent	Relative Soybean Yield Percent
Conventional Cropping		
Wheat or soybeans (soybeans planted May 9)	100*	100†
Double Cropping		
Soybeans planted no-till July 8	92	24
Wheat windrowed and soybeans planted no-till June 30	77	28
Relay Intercropping		
Soybeans planted no-till in skip-row wheat		
April 21	75	15
April 30	67	29
May 9	58	43
Soybeans broadcast in wheat		
April 21	93	8
April 30	95	9
May 9	85	21
Soybeans planted no-till in wheat		
April 21	90	8
April 30	87	14
May 9	77	26
Smallest difference statistically significant at the 95 % confidence level	8	10

*60 bu/A.

†29 bu/A.

TABLE 2.—Effects of Various Planting Methods and Herbicides on Yields* of Soybeans, Wooster, Ohio, 1975.

Planting Method	Herbicides						
	No Herbicide	Paraquat + Lasso + Lorox	Hoelon	Basagran	Surflan	Hoelon + Basagran	Surflan + Basagran
	Relative Soybean Yield† (%)						
Conventional soybeans	100‡		95	92	89	92	91
Double cropped soybeans	11	24	18	20	38	13	36
Windrowed wheat and double cropped soybeans	20	34	14	17	44	19	39
Soybeans no-till planted into skip-row wheat	30		25	26	34	24	28
Soybeans broadcast into standing wheat	12		18	16	5	14	4
Soybeans no-till planted into wheat	15		18	12	20	11	17

*Yields are averaged over planting dates.

†Relative yield due to herbicides is a measure of control of annual grasses, annual broadleaves, red clover, and volunteer wheat. The amounts of herbicides (lb. active chemical) used per acre were: $\frac{1}{2}$ Paraquat, $1\frac{1}{2}$ Lasso, $\frac{1}{2}$ Lorox, 1 Hoelon, 1 Basagran, and $1\frac{1}{2}$ Surflan.

‡30 bu/A. Smallest difference statistically significant at the 95 % confidence level is 7 %.

but is safe on wheat and soybeans at a lower rate if applied early. It is expected that some herbicides will be labeled for wheat and soybeans for application in a relay intercropping system.

Based on 1975 results, relay intercropping seems to have some chance of success if several problems can be resolved. The best wheat and soybean planting pattern, rate of seeding, and time of seeding must be determined. The varieties used in 1975 were too early maturing for relay intercropping. Weed control needs much more work.

1976 EXPERIMENT

Materials and Methods

The experiment in 1975-76 was on a Wooster silt loam having a soil test $\text{pH} = 6.8$, $\text{P} = 65 \text{ lb/A}$, and $\text{K} = 290 \text{ lb/A}$. Arthur-71 wheat was sown in the fall of 1975 with 18-72-72 lb/A of N, P_2O_5 , and K_2O , respectively. Surflan was applied at $\frac{3}{4} \text{ lb/A}$ in April before soybean planting. Plot size was 10 ft wide and 40 ft long.

Soybeans (Captan treated) were planted with a four-row no-tillage planter spaced at 21 inches for relay intercropping and 30 inches for double cropping, which was double planted for eight rows 15 inches apart. Williams soybeans planted in 21-inch rows in tilled ground on May 5 served as a control. For double cropping, wheat was windrowed or combined June 29 at 20% moisture and Rampage soybeans were planted June 30. Other wheat was combined July 6 at 13% moisture and Rampage soybeans were planted July 7. Paraquat + Lasso + Lorox was used for weed control. For relay intercropping, Rampage, Beeson, or Williams soybeans were planted April 15, April 23, or May 5 and the wheat was combined June 29, June 30, or July 6.

Results and Discussion

Results for 1976 are shown in Table 3. Yield of wheat alone was 38 bu/A, which is below normal but common for 1976 in this area. Soybean yield at 36 bu/A was also unusually low; 40-50 bu/A is more common. Double cropped soybean yields were about average for this area. However, Rampage may not have been the best choice, since four other double cropped varieties were higher yielding in a variety test nearby. These varieties were Steele, Hodgson, Evans, and Vansoy, which are as early maturing as Rampage.

Delaying planting from June 30 to July 7 caused a substantial loss of soybean yield from 61% to 17% of the control. Windrowing also decreased wheat yield due to shattering and decreased soybean yield due to volunteer wheat competition. The importance of early planting and weed control for double cropped soybeans has been stressed in other Ohio publications (1, 4).

Some of the relay intercropping treatments show promise as profitable methods. It is clear that the late-maturing variety Williams was superior to the earlier Beeson and Rampage for this system. Since the soybeans grow very little under the wheat canopy, there should be a period for vegetative growth after wheat harvest before flowering begins. Williams, which flowered July 14, fulfills this requirement, whereas Rampage was flowering at the time of wheat harvest and Beeson began soon after that.

TABLE 3.—Effects of Various Soybean Planting Methods into Wheat, Wheat Stubble, and Tilled Ground on Yields of Wheat and Soybeans, Wooster, Ohio, 1976.

Cropping System	Relative Wheat Yield Percent	Relative Soybean Yield Percent
Conventional Soybeans		
Williams soybeans planted May 5 in tilled soil		100†
Double Cropping —Soybeans planted no-till after wheat harvest		
Wheat harvested July 6 at 13 % moisture and planted Rampage soybeans July 7	87	17
Wheat harvested June 29 at 20 % moisture and planted Rampage soybeans June 30	100*	61
Windrow wheat June 29 and planted Rampage soybeans June 30	58	44
Relay Intercropping		
Soybeans planted no-till into standing wheat; wheat harvested June 30 at 20 % moisture		
April 15		
Rampage soybeans	100	14
Beeson soybeans	95	25
Williams soybeans	87	56
April 23		
Rampage soybeans	82	14
Beeson soybeans	84	36
Williams soybeans	74	47
May 5		
Rampage soybeans	74	42
Beeson soybeans	68	58
Williams soybeans	71	83
Williams soybeans planted no-till May 5 into standing wheat; wheat harvested July 6 at 13 % moisture	66	64
Smallest difference statistically significant at the 95 % confidence level	11	25

*38 bu/A.

†36 bu/A.

As was true in 1975, later relay planting of soybeans decreased wheat yields, probably due to traffic damage. However, soybean yields increased with later plantings, a result of better stands. Soil temperatures at 2 inches were 55, 64, and 52° F for April 15, April 23, and May 5 plantings, respectively. The declining temperature after the second planting apparently damaged the emerging seedlings of the first two plantings. Drought in May and June (rainfall for the 2 months was 2.1 inches below normal) was harmful to wheat yields and also reduced relay intercropped soybean stands. Normal rainfall in July and August helped the double cropped soybeans; so these yields may have been unusually high when compared to relay intercropped or single cropped soybeans.

Although combined yields of relay intercropped wheat and soybeans were better than either alone in some cases, it is apparent that there could be improvements in the system. In 1976, the best treatment resulted in 30 bu/A soybeans, but 11 bu/A wheat was sacrificed. Furthermore, wheat alone yielded 38 bu/A which causes concern that a favorable wheat yield of 50 bu/A or more would suppress soybean performance to less than break-even yields. This is suggested by the fact that soybean and wheat yields were generally inversely correlated.

CONCLUSIONS

For relay intercropping, wheat and soybean producers should take into account several conclusions that can be drawn at this point. Weed control was not entirely satisfactory, and there are no herbicides labeled for both wheat and soybeans that are considered highly effective. The best chance for good weed control would occur if there were no perennial weed problems and the post-emergence chemicals took care of the annual weeds. Wheat should be harvested carefully so that harvest losses and resulting volunteer wheat are minimized.

Broadcasting soybeans was not a satisfactory technique and this planting method has been discontinued. No-tillage planting seems to be the most effective method, but there was difficulty in establishing a stand of soybeans because of cold soil at the early planting dates. Planting at later dates resulted in more damage to the wheat which could possibly be reduced by planting in the tractor wheel tracks and using a planter with more units in order to reduce tractor damage. The possibility of planting wheat in skipped-row patterns followed by driving and planting soybeans in the skipped spaces has not been fully explored. In previous Ohio studies, wheat yields were not greatly reduced by planting in 14 inch vs. 7 or 8 inch drill rows (3).

Shallow planting of soybeans may reduce the cold soil effect. The authors have used a 1½ to 1¾ inch planting depth but ½ to 1 inch

should be satisfactory because the surface soil tends to remain moist under the wheat cover. Excellent germination and vigor of seed is necessary.

It is expected that the latest varieties which will mature before frost will be most adaptable to relay intercropping. In Ohio, the public varieties in this group are Williams, Calland, Wayne, Woodworth, Bonus, and Cutler-71. Unique varieties may exist which are especially adaptable to relay intercropping, but this possibility has not been investigated by the authors.

Fertilizer requirements have not been thoroughly investigated. For the present it is recommended that soil test levels be adequate for wheat and soybeans, and phosphorus and potassium applications be sufficient to replace nutrients removed by the crop. Nitrogen (N) for wheat is an unknown factor, since N applied to maximize wheat yield would increase competition of wheat with the interplanted soybeans. Total N applied to wheat should probably be less than 50 lb/A.

Finally, the economic advantage of one cropping system over another will vary from time to time depending upon the relative price of wheat and soybeans. For extreme conditions, wheat alone or soybeans alone would be the best choice. Currently, the two-crop system seems to be the most profitable, with soybeans relatively valuable compared to wheat. This would suggest that relay intercropping, where some wheat yield is sacrificed for a favorable soybean yield, is most desirable. However, if wheat should become more valuable, the double cropping system where little wheat yield is sacrificed may be more profitable, even with the lower soybean yield potential of this system. Thus, some management decisions affecting yields of these two crops will tend to vary depending upon market prices. The producer will want to know the kinds of trade-offs he will be making. So studies on relay intercropping and double cropping will continue.

SUMMARY

- Broadcasting soybeans into standing wheat is an unsatisfactory planting method because of poor soybean germination and because of the hazard to soybeans of surface applied herbicides.
- Double cropping soybeans after wheat harvest can be satisfactory because wheat yields are normal. Soybean yield potential is low due to the late planting and the hazards of drought and frost.
- Relay intercropping takes advantage of the relatively high value of soybeans compared to wheat, but there is a trade-off of reduced wheat yield with later soybean seeding which results in higher soybean yields.
- Herbicide weed control can be acceptable for double cropping, but is unsatisfactory for relay intercropping. New effective herbicides will be essential for the latter system.

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